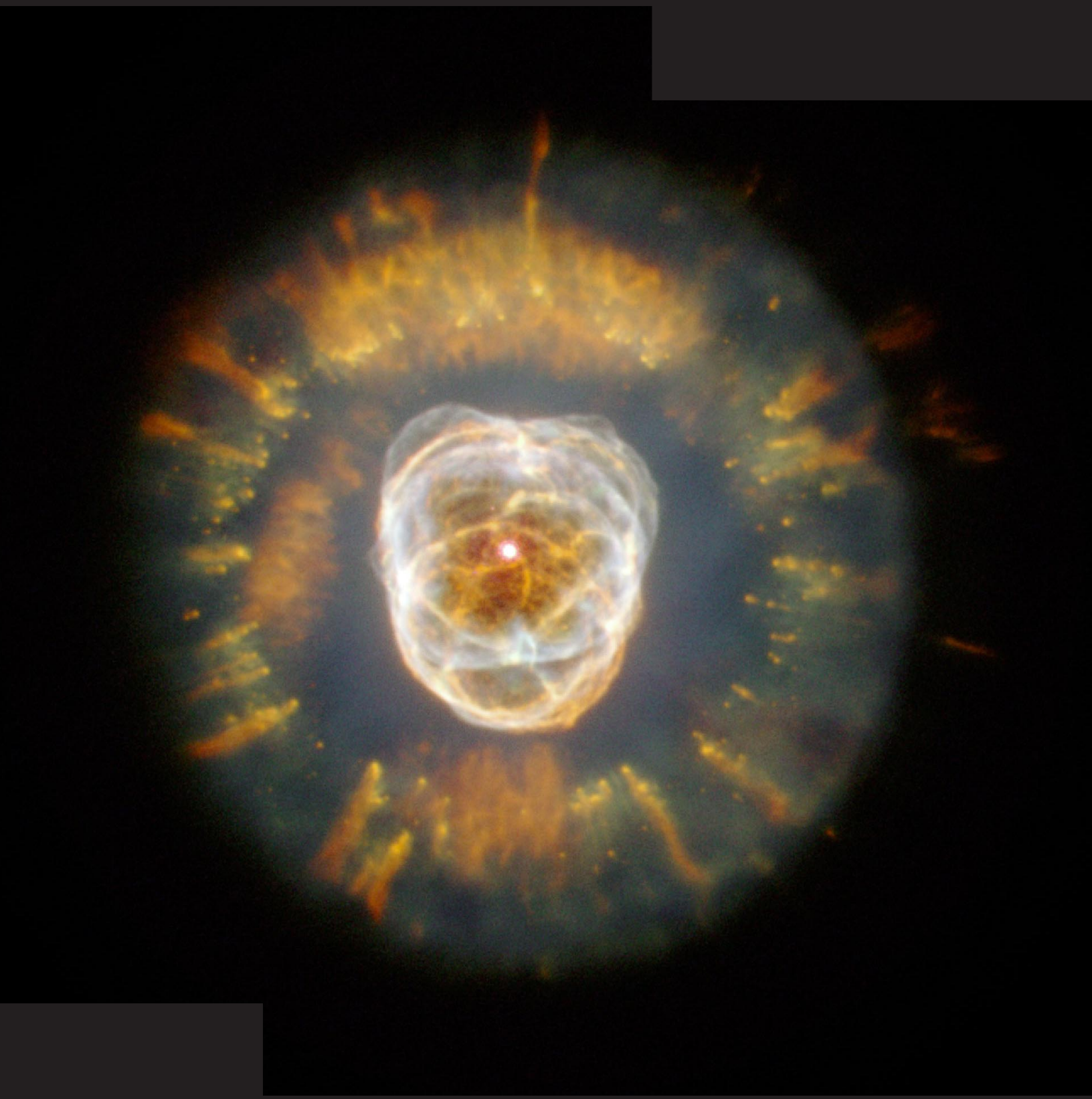


ORIGINS

RESEARCH & ANALYSIS

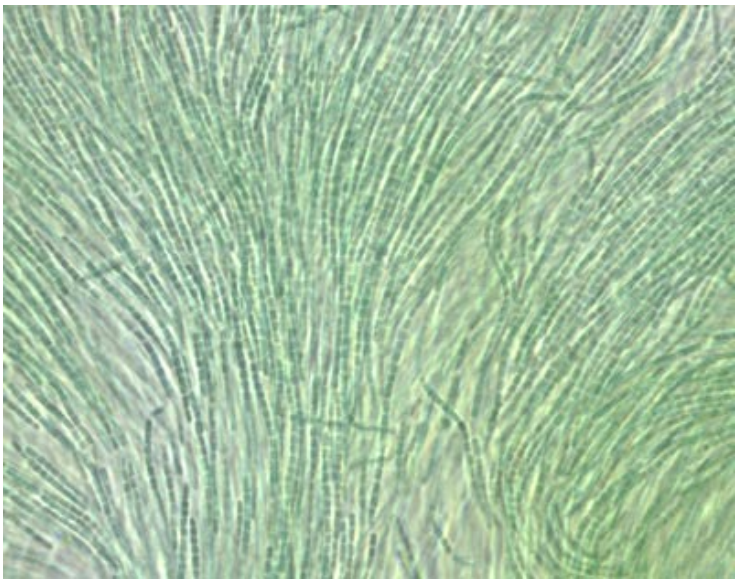
Missions are the highly visible component of NASA's programs. Yet, the major point of contact with the scientific communities that provide the analysis of data obtained by these missions, as well as the scientific underpinning that leads to and ultimately justifies the missions of the future, is through the R&A program. The R&A program provides funding to individual scientists and their research groups so that they may conduct the necessary experimental, observational, and theoretical work that is in direct support of the flight programs. Funding within the R&A program is highly competitive and determined by peer review of proposals that potential Principal Investigators (PIs) and their teams submit to NASA in response to a call for proposals, usually in the form of a NASA Research Announcement (NRA). Moreover, it is the PIs that provide the most direct and continuing link between NASA's science programs and the public. The PIs not only help to convey the excitement and relevance of NASA's missions to the taxpayers, they also serve as a resource for expert information and for promoting education and outreach within their local communities.

COMPLEMENTING THE MISSIONS, AN ACTIVE R&A PROGRAM PROVIDES MANY ESSENTIAL COMPONENTS OF THE ORIGINS THEME.

Complementing the missions is an active R&A program that provides many essential components of the Origins Theme: (1) development of key technologies, such as future detectors, that will be necessary for Origins missions; (2) a broad program of scientific analysis that is critical for the understanding of the vast amounts of data expected from space missions in the coming decade; (3) laboratory astrophysics to determine the properties of atoms, molecules, and dust grains also found in interstellar space, and (4) a program of research with ground-based and airborne telescopes to complement space observatories and develop new instrument technologies.

The Origins Theme R&A program also includes astrobiology. Astrobiology research is just beginning to establish a robust intellectual foundation of how life could begin, where life is possible in the Universe, and what its future is on Earth and beyond its planet of origin. The research will broaden our understanding and enable accurately focused missions in the search for extraterrestrial life. Astrobiology encompasses two grant programs: (1) NASA's Exobiology Program, which sponsors research centered on pathways leading to and from the origin of life, not only to understand the origin of life on Earth but also to establish the basis upon which it will be possible to determine the potential for life elsewhere in the Universe; and (2) a new Evolutionary Biology Program that seeks to understand the physical and biological forces that affect biological evolution and the interaction of life with its environment. In addition, NASA has established a National Astrobiology Institute (NAI) — a nontraditional "institute without walls" whose members conduct proposed interdisciplinary research and yet are geographically dispersed.

A key area for Origins research is the need for a catalogue for global biosignatures. The approach is to determine the details of the co-evolution of Earth and life and then test hypothetical biospheres. The biosphere of Earth has changed through time from possibly anoxic, to neutral, to the highly oxidized atmosphere of today. With recent improvements in geologic dating techniques, the geologic record can be used to track the changes in Earth's biosphere and, combined with the phylogenetic record, match the milestones of evolution and the products affecting the geologic record. Genetic information may determine the sequence of biological steps in the growing complexity of cellular components and functions. Furthermore, studies in microbial ecology will enhance our understanding of how life progresses from a local phenomenon to being globally persistent, and the evolving consequences on the surrounding environment. By deriving first principles from the terrestrial record, we

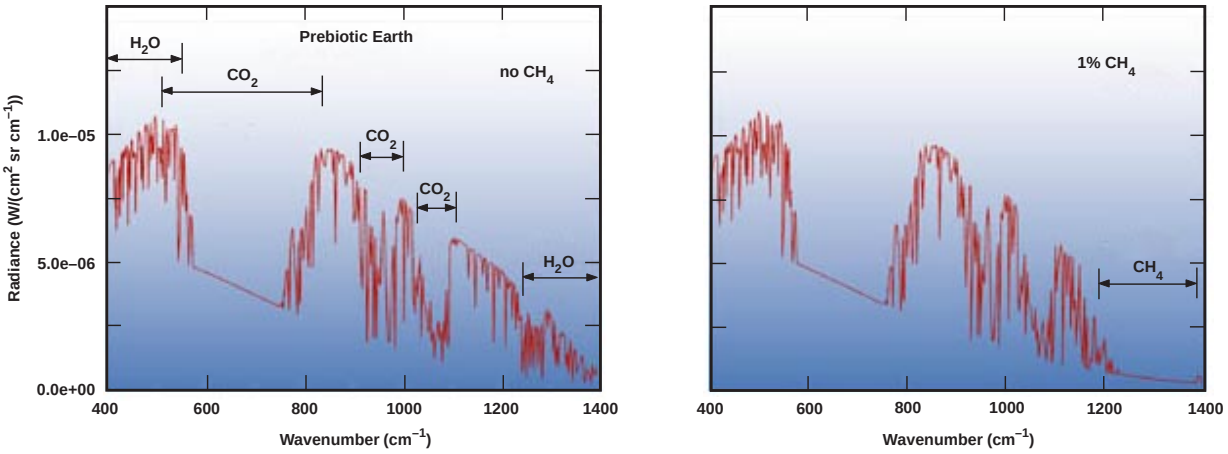


A microphotograph of cyanobacteria (bluegreen algae) that photosynthesize carbon dioxide to produce oxygen.

can develop a theoretical framework for potential biosignatures of planets at different stages of evolution and experimentally test atmospheres generated by different suites of microbial systems under alternative planetary conditions.

Extreme environments could play a crucial role in astrobiology research in identifying the extremes of life and identifying areas that are analogous to potentially habitable extraterrestrial environments, past or present, and the early Earth. Furthermore, conducting research in extreme environments will allow us to gain experience in exploring novel harsh environments in the search for the signs of life. NASA has conducted research in extreme environments and recently teamed with the National Science Foundation (the Life in Extreme Environments Program), to support long-term studies of sites in extreme environments, specifically to improve the science and exploration of these habitats.

Theoretical and laboratory studies are also pivotal to interpreting and guiding astronomical studies of the formation of galaxies, stars, and planetary systems. Much of the



Methane-producing bacteria could have had a profound effect on the atmosphere of the early Earth, producing strong absorption around 7.6 μm (1300 cm^{-1}).

research in these areas is currently conducted through the Interdisciplinary Origins R&A Program. These studies need to be continued and expanded to keep pace with the increasing flow of data that is coming from flight missions, and which is expected to increase further with implementation of the missions outlined in this Roadmap.

An important step in the evolution of the R&A program, particularly in the Interdisciplinary Origins R&A Program, is the establishment of a new type of grant. At present most of the grants are for single investigators, with perhaps a small number of students. The Astrobiology R&A Program has a similar structure, but it also has the NAI, a large (~$10M/yr) expenditure that flows through a single entity.

The new element is for consortia of a small number of investigators working on an interrelated set of problems. These problems would be too large or too diverse for a single researcher. The level of funding for such consortia would be roughly $500K to $1000K per annum per consortium, with durations of five years. Similar programs have been successful in the past in studies of the Sun and in theoretical astrophysics.

It is through basic research that a broad and diverse scientific community generates the knowledge gained from missions and formulates the next steps in exploration.

New NASA missions, as well as ground-based surveys, are already providing tens of terabytes of catalog and image data for the astronomical community and will be providing petabytes of data by the end of the next decade. The integration of the separate archives, covering many different wavelengths and many different epochs, into a seamlessly interoperating entity will allow true multiwavelength astronomy to be performed on entire classes of objects. The technologies needed to enable this high level of integration are at the leading edge of the ongoing revolutions in hardware and software. NASA should play a key role in fostering these developments in the coming decade.

THROUGH BASIC RESEARCH, THE SCIENCE COMMUNITY FORMULATES THE NEXT STEPS IN EXPLORATION. AN IMPORTANT STEP IN THE R&A PROGRAM IS THE ESTABLISHMENT OF A NEW TYPE OF GRANT.